DICKERSON

Tests of a Locomotive Injector

Mech. Engineering
B. S.

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TESTS OF A LOCOMOTIVE INJECTOR

BY

GEORGE HAMM DICKERSON

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

IN THE
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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

GEORGE HAMM DICKERSON

ENTITLED TESTS OF A LOCOMOTIVE INJECTOR

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering.

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

INTRODUCTION

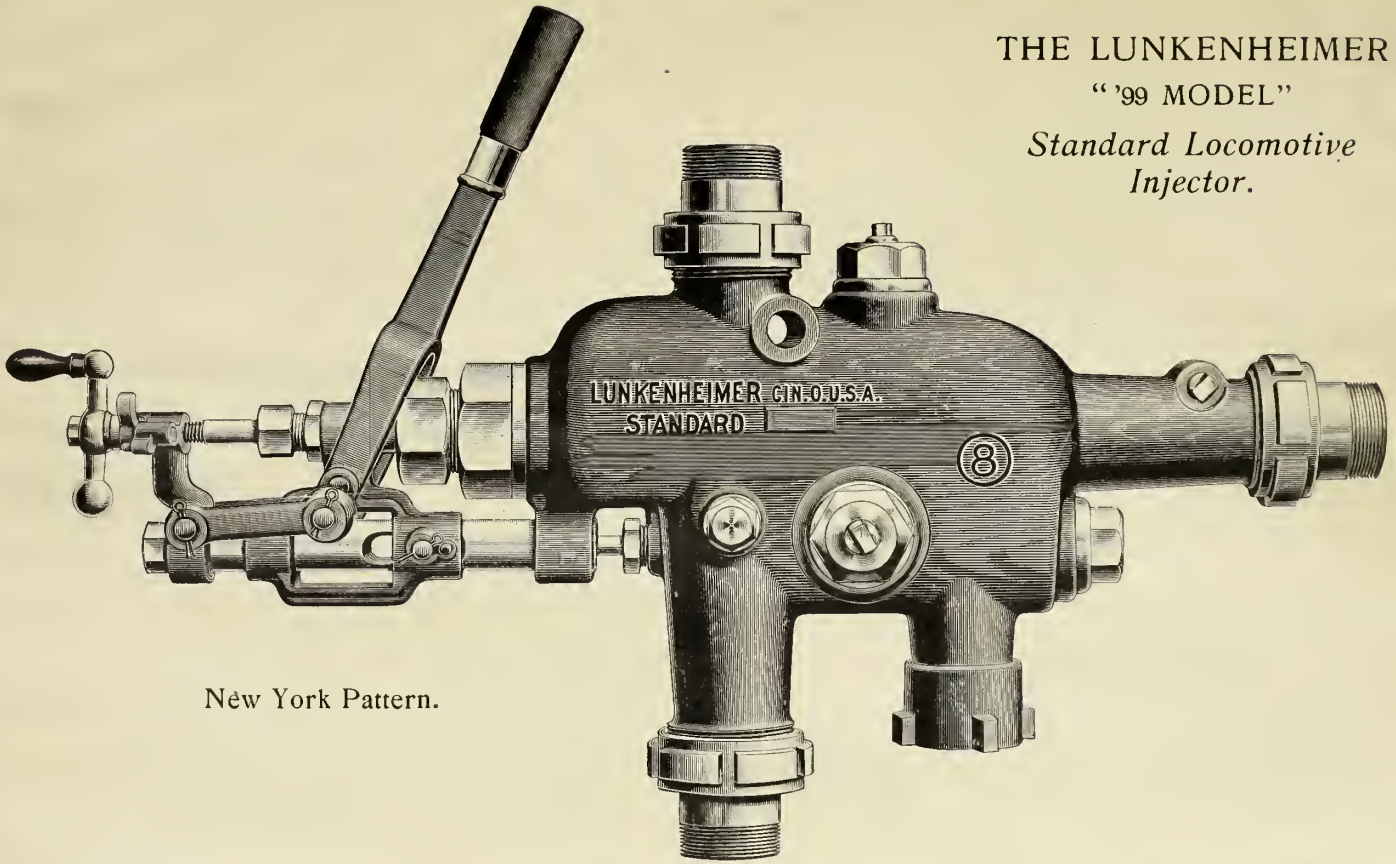
The subject matter herein contained is presented as a thesis for graduation in the Mechanical Engineering Department of the University of Illinois.

The tests herein tabulated and described were made by the author during the spring of 1903, at the University of Illinois, Urbana, Illinois. The injector tested was a standard locomotive injector made by the Lunkenheimer Mfg. Co., Cincinnati, Ohio.

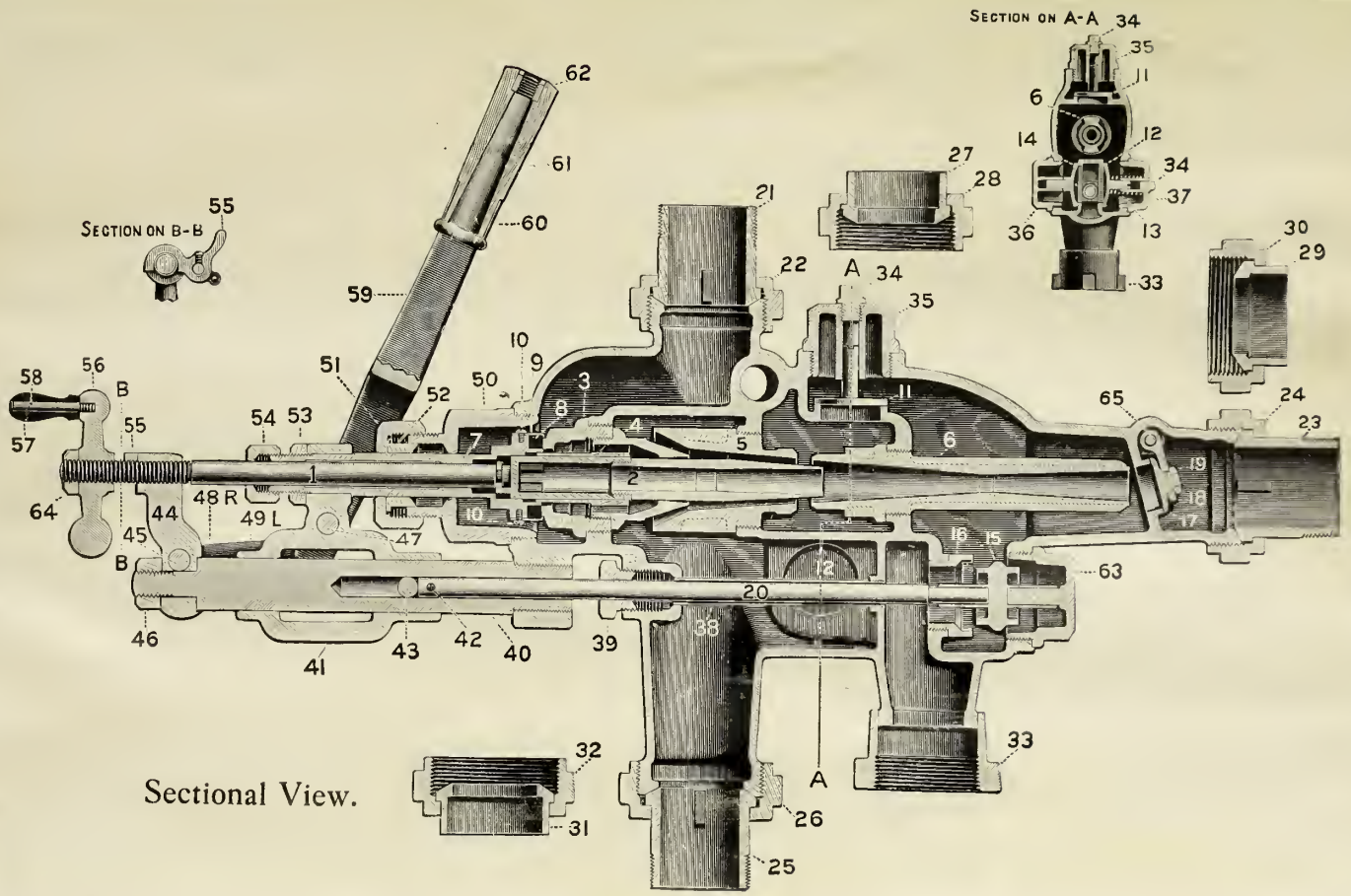
THE LUNKENHEIMER

"'99 MODEL"

Standard Locomotive Injector.



New York Pattern.



Sectional View.

List of Parts.

1 Regulating Rod.
2 Steam Forcing Tube.
3 Steam Valve Seat.
4 Huddler.
5 Water-Lifting Tube.
6 Forcing Combining Tube.
7 Steam Valve.
8 Steam Valve Disc.
9 Disc Holder.
10 Retaining Screws.
11 Intermediate Overflow Valve.
12 Auxiliary Water Valve.
13 Auxiliary Water Valve Spring.
14 Blind Valve.
15 Final Overflow Valve Disc.
16 Final Overflow Valve Seat.
17 Line Check Disc.
18 Line Check Disc Carrier.
19 Line Check Disc Locknut.
20 Final Overflow Valve Rod.
21 Union Tailpiece for Iron Pipe Steam Connection.
22 Union Ring for Iron Pipe Steam Connection.
23 Union Tailpiece for Iron Pipe Discharge Connection.
24 Union Ring for Iron Pipe Discharge Connection.
25 Union Tailpiece for Iron Pipe Suction Connection.
26 Union Ring for Iron Pipe Suction Connection.
27 Union Tailpiece for Copper Pipe Steam Connection.
28 Union Ring for Copper Pipe Steam Connection.
29 Union Tailpiece for Copper Pipe Discharge Connection.
30 Union Ring for Copper Pipe Discharge Connection.
31 Union Tailpiece for Copper Pipe Suction Connection.
32 Union Ring for Copper Pipe Suction Connection.
33 Overflow Coupling.
34 Regrinding Plugs.
35 Intermediate Overflow Valve Cap.
36 Blind Cap.
37 Auxiliary Water Valve Cap.
38 Final Overflow Valve Rod Casing.
39 Final Overflow Valve Stuffing Box.
40 Guide Rod.
41 Steam Valve Carrier.
42 Cotter for Final Overflow Rod.
43 Pin for Overflow Rod.
44 Guide for Regulating Rod.
45 Pin for Side Bars.
46 Locknut on Guide Rod.
47 Lever Pin.
48 Side Bars for Lever, Right.
49 Side Bars for Lever, Left.
50 Bonnet.
51 Stuffing Box.
52 Gland.
53 Locknut on Steam Valve Stem.
54 Stuffing Box on Steam Valve Stem.
55 Heater Stop.
56 Crank.
57 Crank Handle.
58 Crank Handle Pin.
59 Lever.
60 Ferrule.
61 Handle.
62 Handle Screw.
63 Final Overflow Valve Cap.
64 Locknut on Regulating Rod.
65 Pin for Line Check Valve.
66 Plugs for Line Check Valve.

I OBJECT.

The object of these tests was to investigate the performance of the injector under the following conditions:

A. Different steam pressures, the suction lift, suction temperature, and delivery pressure being kept constant.

B. Different suction lifts, the steam pressure, suction temperature, and delivery pressure being kept constant.

C. Different delivery pressures, the steam pressure, suction lift, and suction temperatures being kept constant.

II DESCRIPTION OF INJECTOR.

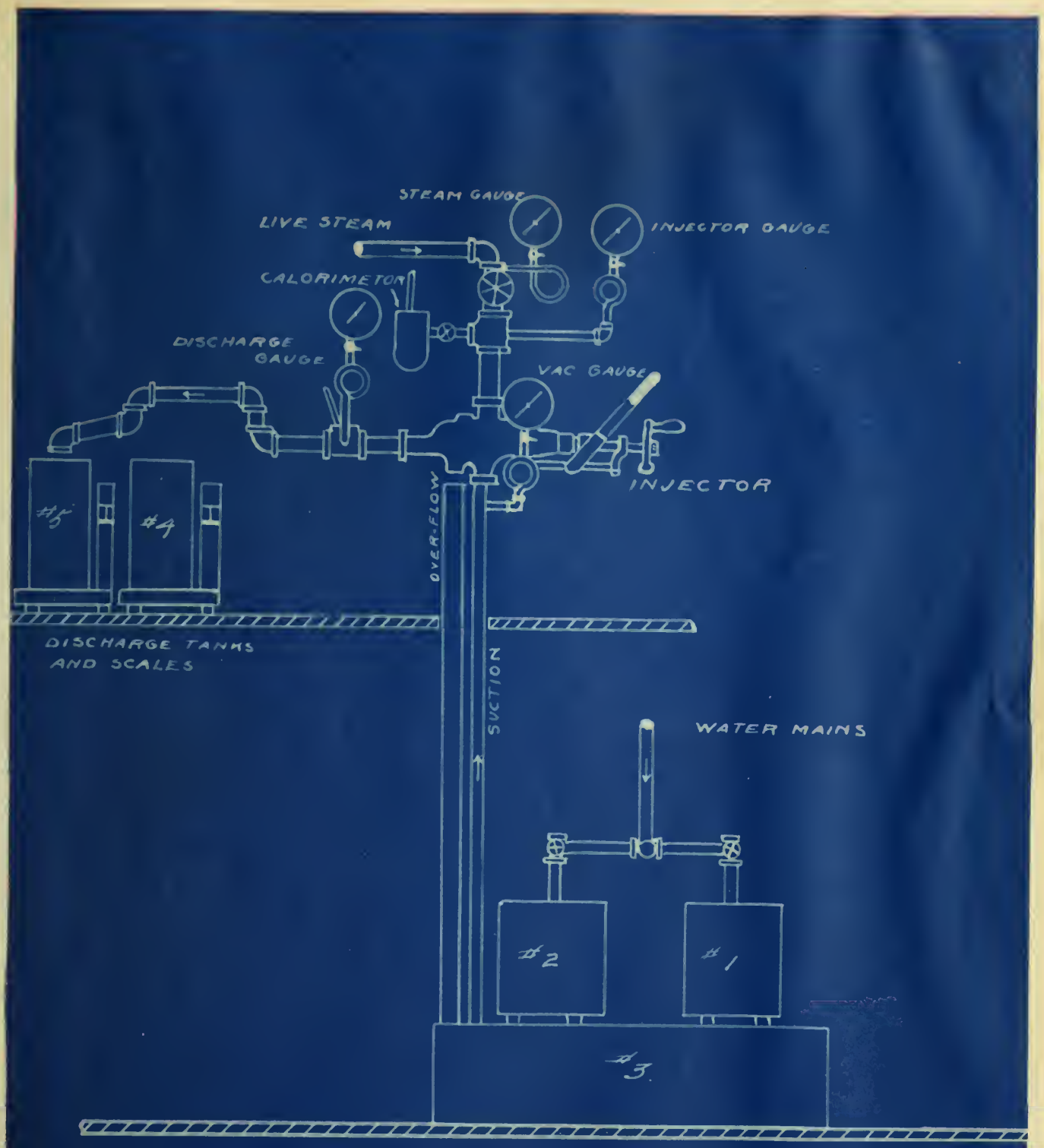
a. The injector, of which a cut appears on the opposite page. is a #8 Locomotive Injector made by the Lunkenheimer Mfg. Co., Cincinnati, Ohio, and is listed in their catalog as "The Lunkenheimer '99 Model' Standard Injector." The parts of the injector are shown in the following sectional cut and are tabulated so that they need no description.

b. Method of Operation. - In starting the lever (59) is drawn back slightly(see sectional cut). This movement draws the steam valve (7) back and unseats same partially, which admits the lifting steam through cap (3) and the huddler (4), out around the steam tube (2), into the water lifting tube (5), opening the valve (11), and exhausting partially through the valve (4), and also through the tube (6), and out through the overflow valve (15) in to the atmosphere. The steam thus exhausted exerts a strong draught in the

suction branch, discharges the air, and the water is forced up by atmospheric pressure, i.e. "lifted." When water appears at the overflow the lever (59) is drawn all the way back. This movement uncovers the ports in the movable steam tube, admitting the jet of forcing steam, which drives the water through the forcer combining tube (6). By the same movement of the lever (59) the rod (20) is withdrawn and valve (15) is seated by the increasing pressure in the delivery chamber. Valve (11) is also seated by the pressure on the top of same, and all water is forced through the tube (6), overcomes the boiler pressure on line check valve (17) and passes into the feed pipe. The amount of water delivered is regulated by the movable steam tube (2). This tube moves longitudinally through the other tubes in the machine and is actuated by the threaded stem (1) and crank (56). To deliver the maximum amount of water the tube is withdrawn to its limit. This admits the maximum amount of steam around the outside of the tube to lift the water, and also to the interior of same to force the jet into the boiler. The withdrawal of tube (2) also increases the passageway around same and through tubes (5) and (6). When it is desired to reduce the capacity, the crank (56) is turned from left to right, which forces the tube (2) into the openings in tubes (4),(5),and (6).The effect of this is:

FIRST.- To cut off the amount of forcing steam passing through the ports in the end of the tube (2) as same is moved into the tubular extension of huddler (4).

SECOND.- It decreases the passage of lifting steam around tube



SKETCH SHOWING ARRANGEMENT OF APPARATUS FOR INJECTOR TEST.

(2) and through huddler (4), due to the tapering diameter of tube (2) approaching the fixed internal diameter of huddler (4).

THIRD.- The passageways through tubes (5) and (6) are decreased as the tube (2) is passed into same.

The auxiliary water valve (12) is situated at the side of the machine and controls the port between the suction branch and the intermediate chamber of the injector; see sectional cut. The function of this valve is to make the injector self-adjusting and unaffected by variations of steam pressure. At certain pressures the water lifting tube does not deliver a sufficient quantity of water to condense the steam, and at such times the vacuum formed in the chamber causes the valve (12) to open and admit the additional amount of water required.

b. Description of Apparatus.-

The apparatus used consisted of:-

1 Lunkenheimer Standard Injector.

3 Steam Gauges.

1 Vacuum Gauge.

1 Steam Separator.

1 Schaeffer and Budenberg Calorimeter.

3 Thermometers.

4 Measuring Tanks.

A diagrammatic sketch of the apparatus may be seen on the opposite page.

The two tanks #1 and #2 receive the suction water from the city mains and deposit it in the reservoir tank #3 from which it is drawn by the injector. The delivery water passes over and is caught in tanks #4 and #5. These tanks rest on scales as shown and are so

balanced, that when a definite quantity of water is caught the scale beam rises and warns the operator. When tank #4 or #5 is opened the water flows away to the sewer.

The steam separator serves to extract a portion of the moisture in the steam.

The calorimeter is a simple throttling calorimeter and is exhaustively described in the Schaeffer and Budenberg catalog. Its purpose is to determine the percentage of moisture in the steam used.

A thermometer in tank #3 gives the temperature of the suction water and one shown in the pipe to the left of the injector gives the temperature of the delivery water.

As shown in the sketch one gauge registers the steam pressures in the mains, another the steam pressures at the injector, and the third shows the delivery pressure. By means of the two throttle valves shown in the sketch the suction or delivery pressures can be regulated.

c. Method of Procedure.- The injector is started as described on page 2. When everything is running smoothly the water in tank #3 is brought to a reference level mark and the delivery water turned into the tank #4. Readings are taken of the steam pressure at the injector, the suction lift, the suction temperature, the delivery pressure, the delivery temperature, and of the steam temperature in the calorimeter. These readings are taken at five minute intervals during a half hour test and at 3 minute intervals during a fifteen minute test.

The operator has tank #1 full at the start and when the test is started he allows its contents to flow into tank #3. While tank #1 is emptying he is filling tank #2. The tanks are thus alternately filled and emptied, and a record of the time of emptying is kept. By means of the valve at the bottom of the tank the discharge is so regulated that the water in tank #3 remains at a practically constant level. This insures a constant suction lift.

When the scale beam in the scale under tank #4 rises the water is turned into tank #5 by means of the swing joint shown in the sketch, and the valve on tank #4 opened, which allows the water to escape to the sewer. When tank #5 is filled the water is turned back into tank #4 and it is again filled while tank #5 is being emptied. A careful record of the time of emptying of each tank is kept. If at the end of the test any water be left in either tank #1 or tank #2 it is let flow into tank #3 which is calibrated for height, and the amount to be subtracted from the toal number of full tanks is thus ascertained.

When running tests A the steam pressure is kept constant during each test by means of the valve shown in the sketch. When running tests B and tests C, 100 lbs. steam pressure was selected as representing current stationary boiler practice, and 200 lbs steam pressure as representing current locomotive boiler practice. As stated before, the delivery pressures in tests C were regulated by means of the valve shown in the delivery pipe. In like manner the suction lifts in tests B were regulated by the throttle valve in the suction

pipe.

d. Calibrations.- All the instruments used were carefully calibrated as follows:-

The thermometers were calibrated by comparison with the standard thermometer, of the University of Illinois, in a steam bath surrounded by non-radiating covering. The calibration curves of the thermometers and gauges may be seen on a succeeding page.

The steam gauges were calibrated on a Crosby standard oil gauge tester. The vacuum gauge was calibrated by means of an air pump and mercury manometer. The gauge and manometer were both attached to the air pump and a vacuum maintained by the pump while the comparison between the gauge and manometer was made.

The supply tanks #1 and #2 were filled and the contents weighed. This was repeated (5) five times and the average reading taken as the contents. Tank #3 was calibrated for each inch of height in like manner and a guage fastened to the inside. The scales under tanks #4 and #5 were calibrated by a U.S. standard 50# weight.

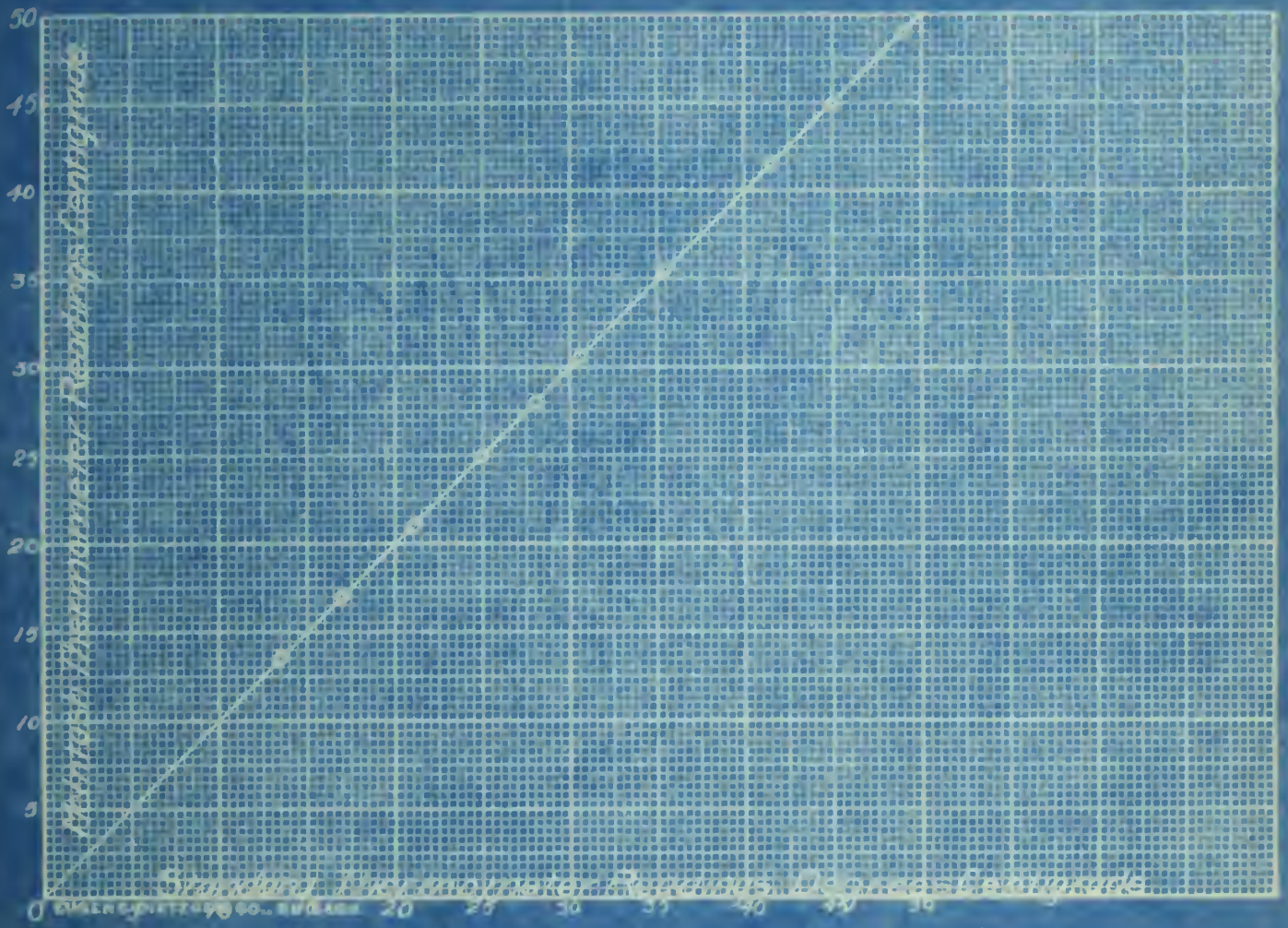
Tank #1 will hold 708# water at 58° F.

Tank #2 will hold 702# water at 58° F.

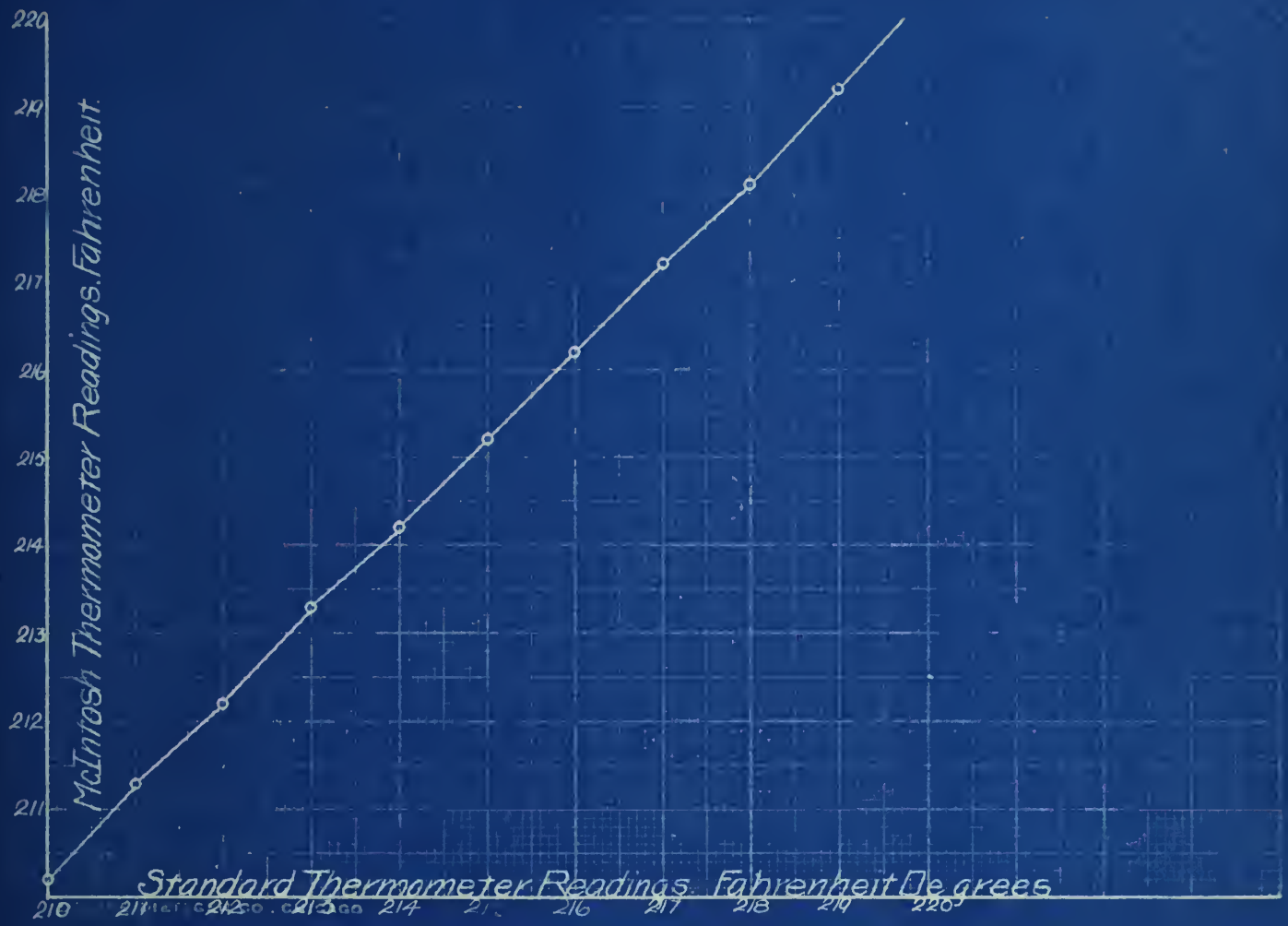
Tank #3 will hold 57.5# for each inch at 58° F.

The following list indicates which thermometers were used at the different points.

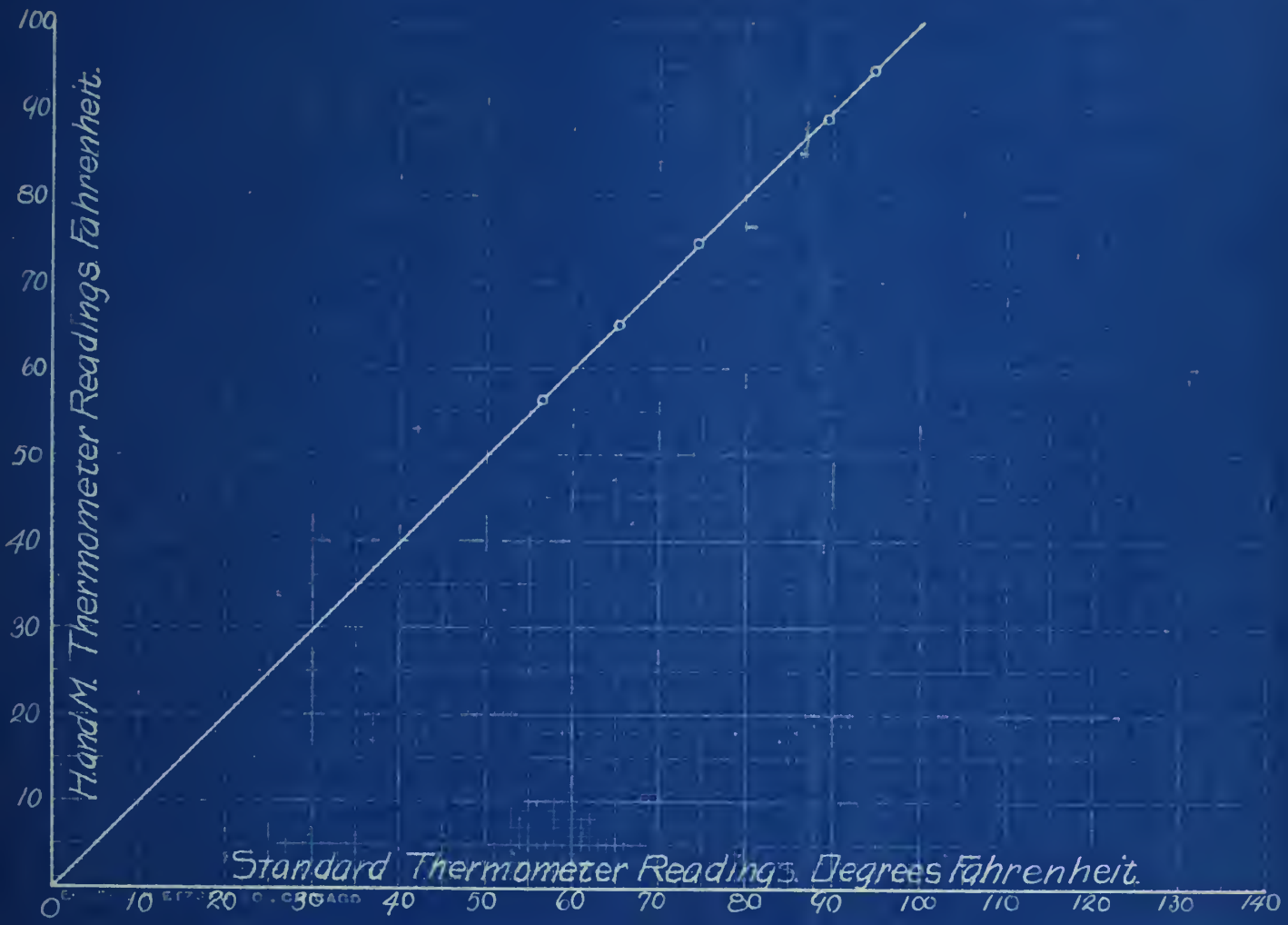
For Supply Water, Hohman & Maurer	#24848.
For Delivery Water, Mc Intosh Inventory	#45.
For Calorimeter, Mc Intosh Inventory	#46.
For Steam Pressure at Injector use Crosby Gauge	#384143.
For Delivery Pressure use Crosby Gauge	#384144.
For Suction Lifts use Vacuum Gauge	#420405.



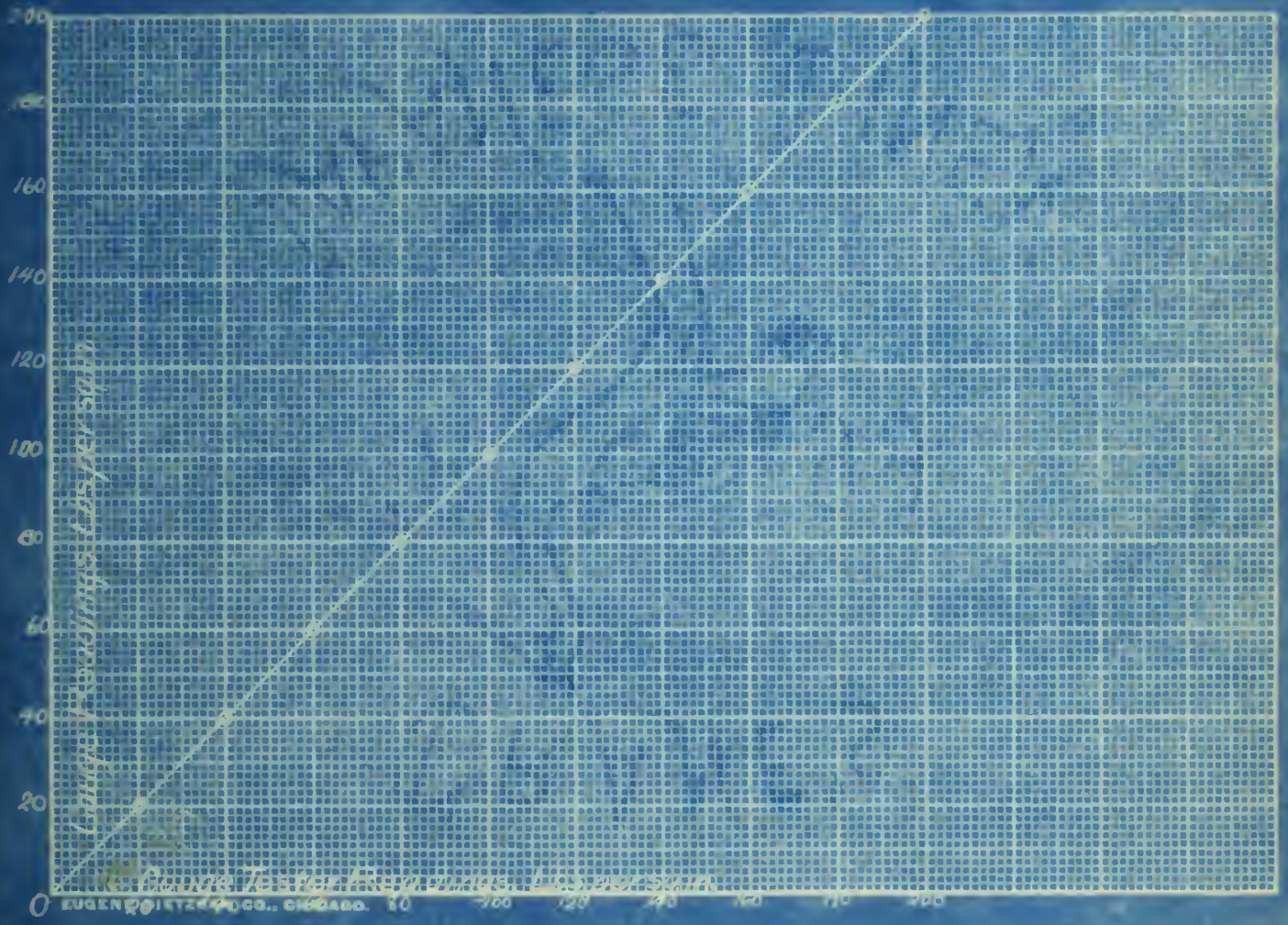
CALIBRATION CURVE
OF
McINTOSH THERMOMETER *45



CALIBRATION CURVE
OF
McINTOSH THERMOMETER #46



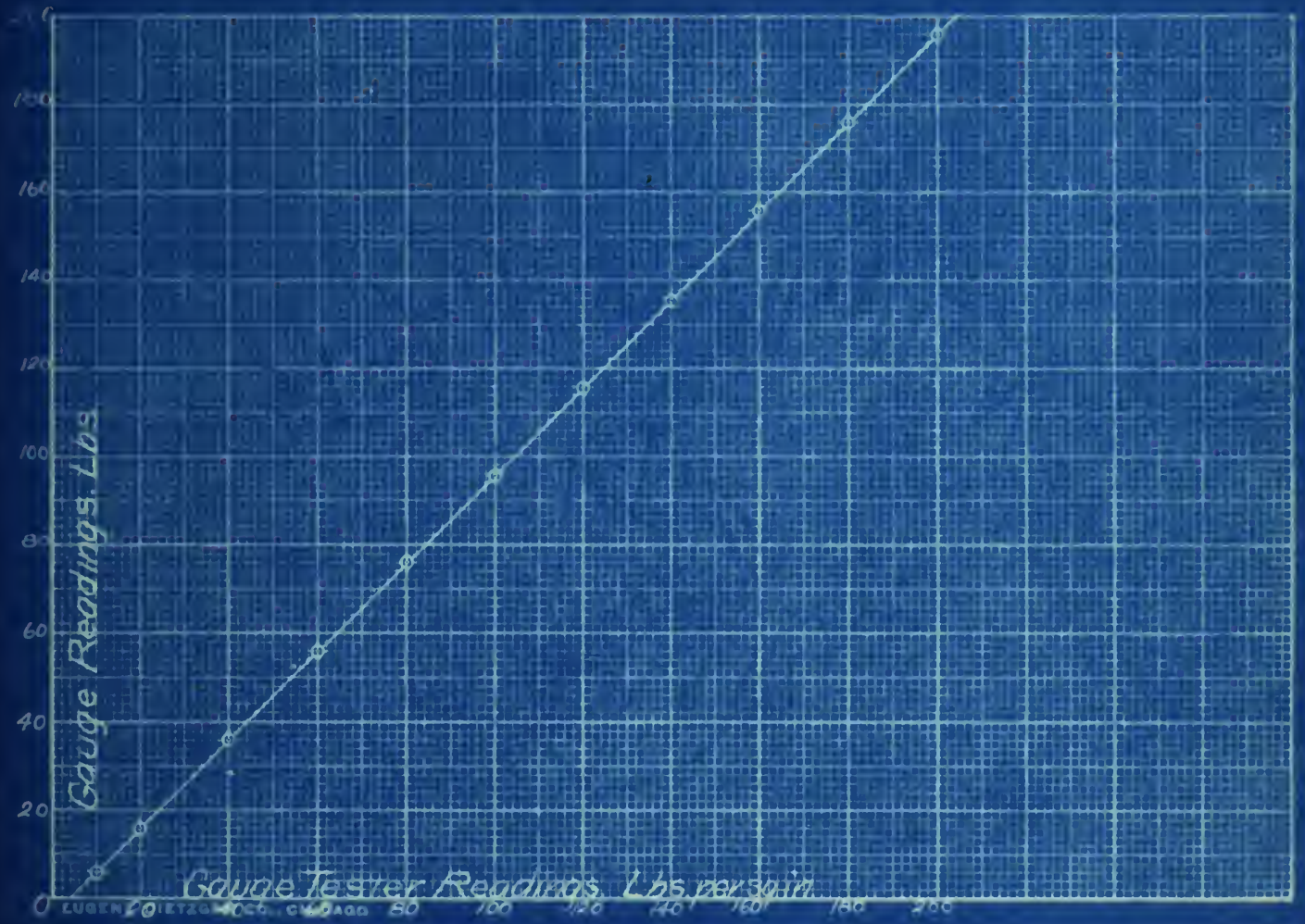
CALIBRATION CURVE
OF
HOHMAN AND MAURER THERMOMETER # 24848.



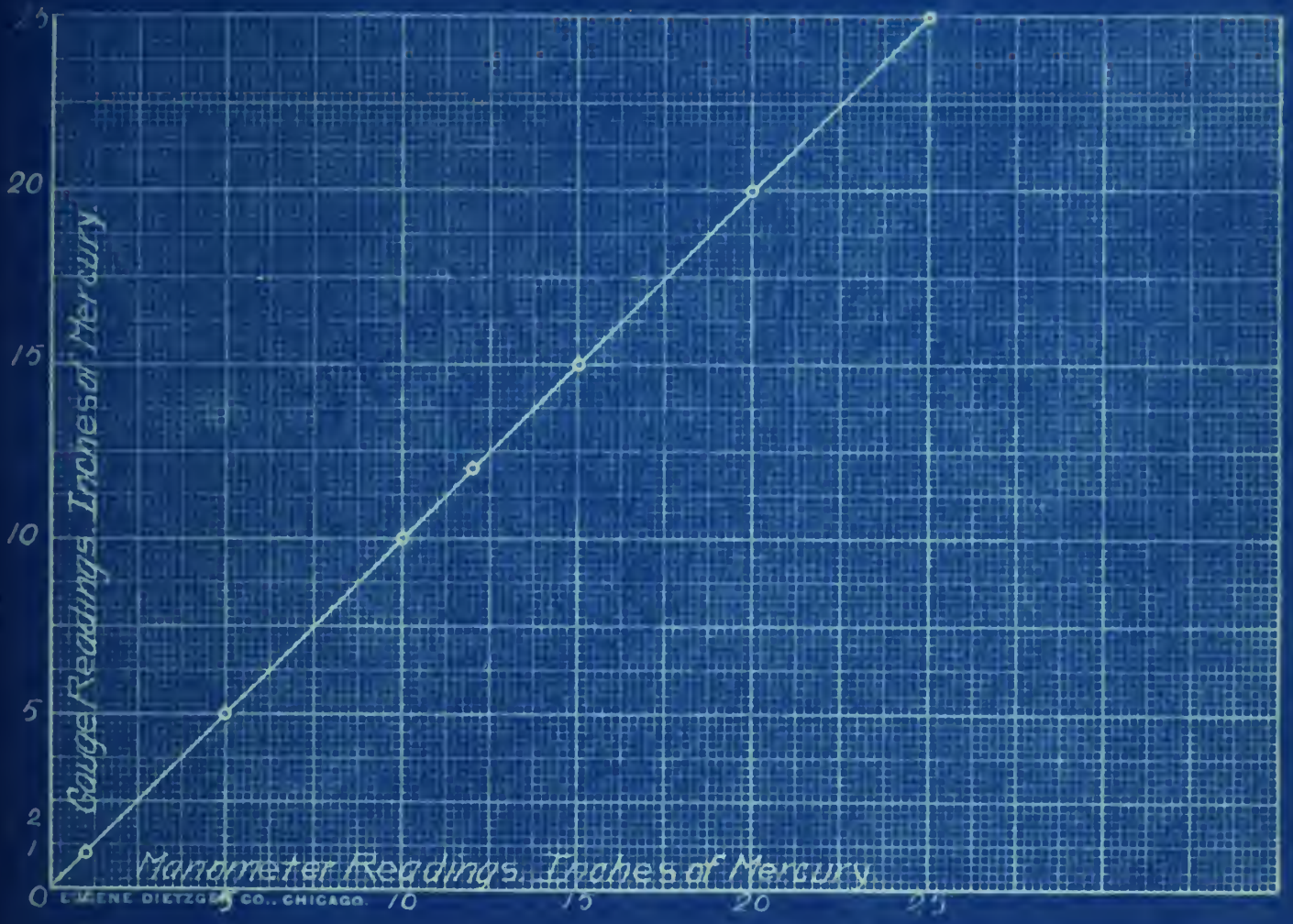
CALIBRATION CURVE

OF

CROSBY STEAM GAUGE #384143.



CALIBRATION CURVE
OF
CROSBY STEAM GAUGE #384144.



CALIBRATION CURVE

OF

VACUUM GAUGE #420405

III D A T A

Log Sheet Test #1

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
11:23	20	6	0	104°C	57°F	39°C		702			
11:28	20	6	0	104	58	39	708			700	
11:32	20	6	0	104	57	38		702			700
11:36							708			700	
11:38	20	6	0	104	57	39					
11:40								702			700
11:43	20	6	0	104	58	38					
11:45							708			700	
11:48	20	6	0	104	58	38					700
11:49								702			
11:50											
11:53	20	6	0	104	58	38			-3½"	700	262

Log Sheet Test #2

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:35	40	6	0	126°C	56°F	42°C		702			
2:38							708			745	
2:40	40	6	0	121	56	41					
2:41								702			700
2:45	40	6	0	116	56	41	708			700	
2:47								702			700
2:50	40	6	0	112	56	41	708			700	
2:53											700
2:54								702			
2:55	40	6	0	110	56	40					
2:56										700	
2:57							708				
2:59											700
3:00	40	6	0	109	56	41		702			
3:02										700	
3:03							708				
3:05									-4"	100	700

Log Sheet. Test #3

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
10:47	60	6	0	100°C	62°F	51°C	708	702			700
10:50											
10:52	60	6	0	104	61	51		702		700	
10:53											
10:55	60	6	0	105	60	51	708				
10:56											
10:57	60	6	0	106	59	51					
10:58	60	6	0	108	58	50					
10:59								702			
11:01											700
11:02	60	6	0	110	58	50	708				
11:04										700	
11:05								702			
11:07	60	6	0	112	58	48	708				700
11:10										700	
11:11								702			
11:12	60	6	0	113	57	49					700
11:13											
11:14										700	
11:15							708				
11:17								15	±0"		410

Log Sheet Test #4

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
1:18	80	6	0	109°C	57°F	50°C		702			
1:21							708			700	
1:23	80	6	0	118	57	52		702			700
1:25							708			700	
1:27								702			700
1:28	80	6	0	116	57	51					
1:30							708			700	
1:32								702			700
1:33	80	6	0	116	57	51					
1:34							708			700	
1:36								702			700
1:38	80	6	0	115	57	50				700	
1:39							708				
1:40											700
1:41								702			
1:42										700	
1:43	80	6	0	112	57	50	708				
1:44											700
1:46								702			
1:47										700	
1:48	80	6	0	115	57	53			-1¼"	400	700

Log Sheet Test #5

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steamin Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
8:47	100	6	0	106°C	59°F.	53°C		702			
8:50							708			700	
8:52	100	6	0	113	59	50		702			700
8:54							708			700	
8:56								702			700
8:57	100	6	0	116	57	50					
8:58							708			700	
9:00								702			700
9:02	100	6	0	117	56	49				700	
9:03							708				
9:04											700
9:05								702		700	
9:07	100	6	0	119	56	51	708				700
9:09								702		700	
9:12	100	6	0	120	56	54	708				700
9:14								702		700	
9:16							708				700
9:17	100	6	0	119	56	54			-4½"	500	

Log Sheet. Test #6

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
12:57	140	8	0	108°C	68°F	69°C		702			
1:00	140	8	0	108	68	69	708			700	
1:02								702			700
1:03	140	8	0	112	67	68					
1:04							708			700	
1:05	140	8	0	116	66	69		702			710
1:07	140	8	0	117	65	69				700	
1:08							708				
1:10	140	8	0	115	64	75		702			700
1:12	140	8	0	114	64	76			-1"	700	425

Log Sheet Test #7

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height.	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
11:06	160	8	0	115°C	70°F	77°C		702			
11:08							708			700	
11:10	160	8	0	122	66	77		702			700
11:12										700	
11:13	160	8	0	126	65	77	708				
11:15	160	8	0	130	64	76		702			700
11:16										700	
11:17							708				
11:18	160	8	0	127	64	76					700
11:20								702		700	
11:21	160	8	0	130	63	77			$-\frac{3}{4}$"		450

Log Sheet Test #8

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
9:15	180	8	0	124°C	62°F	81°C		702			
9:17							708			700	
9:18	180	8	0	128	62	82					
9:19								702			700
9:20	180	8	0	127	63	84					
9:21							708			700	
9:23	180	8	0	129	63	81		702			700
9:25	180	8	0	128	62	81				700	
9:26							708				
9:27											700
9:28	180	8	0	124	60	79		702			
9:29										700	
9:30	180	8	0	125	59	79			-1"		635

Log Sheet Test #9

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs	Tank #5 Wt. Lbs
9:53	200	8	0	116°C	58°F	84°C		702			
9:55	200	8	0	118	58	84	708			700	
9:57											710
9:58	200	8	0	118	58	88		702			
9:59										700	
10:00	200	8	0	118	58	88	708				
10:01											700
10:03	200	8	0	117	57	89		702		700	
10:05	200	8	0	122	57	91	708				700
10:07										700	
10:08	200	8	0	124	57	91			+5 3/4"		400

Log Sheet Test #10

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
4:29	100	6	0	116°C	67°F	68°C		702			
4:32							708			700	
4:33	100	6	0	118°C	67	66					
4:34								702			700
4:35	100	6	0	117	62	65					
4:36							708			700	
4:38	100	6	0	118	59	63					
4:39								702			700
4:40	100	6	0	119	59	57					
4:41							708			700	
4:43											700
4:44	100	6	0	119	59	55			-1½"	145	

Log Sheet. Test #11

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
4:43	100	6	40	117°C	70°F	73°C	708				
4:46								702		725	
4:48	100	6	40	126	65	66	708				700
4:51								702		700	
4:53	100	6	40	125	64	66	708				700
4:56								702		700	
4:58	100	6	40	129	61	64	708				700
5:00										700	
5:01								702			
5:03	100	6	40	128	63	65					700
5:04							708				
5:06										700	
5:07								702			
5:08	100	6	40	128	63	65					700
5:10							708			700	
5:11	100	6	40	126	64	66					
5:12											700
5:13	100	6	40	126	62	66			+3½"	115	

Log Sheet Test #12

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
3:58	100	6	80	121°C	62°F	66°C	708				
4:01								702		700	
4:03	100	6	80	121	62	66	708				710
4:06								702			
4:08	100	6	80	128	62	65				700	
4:09							708				700
4:11										700	
4:12								702			
4:13	100	6	80	129	62	66					
4:14											725
4:15							708				
4:16										700	
4:18	100	6	80	129	62	67		702			
4:19											700
4:20							708				
4:21										720	
4:23	100	6	80	130	62	65		702			
4:24											700
4:26							708				
4:27										700	
4:28	100	6	80	130	62	65			−2¼"		455

Log Sheet. Test #13.

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt Lbs	Tank #5 Wt. Lbs.
2:10	200	8	0	125°C	60°F	94°C		702			
2:13	200	8	0	128	59	91	708			700	
2:15	200	8	0	129	59	91		702			700
2:17										700	
2:18	200	8	0	128	61	92	708				
2:19											700
2:20	200	8	0	130	60	91		702			
2:21										700	
2:22							708				
2:23	200	8	0	128	59	92					700
2:25	200	8	0	128	59	90				700	40

Log Sheet Test #14

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
1:35	200	10	40	125°C	59°F	95°C		702			
1:36							708				
1:37										700	
1:38	200	10	40	126	60	98					
1:39								702			700
1:40	200	10	40	126	59	97					
1:41							708			700	
1:43	200	10	40	128	59	97					
1:44								702			700
1:45	200	10	40	128	59	98					
1:46										700	
1:47							708				
1:48	200	10	40	128	58	98					700
1:50	200	10	40	128	59	98			+½"	600	

Log Sheet Test #15

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:25	200	10	80	118°C	60°F	93°C		702			
2:28	200	10	80	120	60	93	708			700	
2:30	200	10	80	124	60	93		702			700
2:32							708			700	
2:33	200	10	80	125	59	92					
2:34											700
2:35	200	10	80	122	59	94		702			
2:36										720	
2:37							708				
2:38	200	10	80	120	59	94					710
2:40	200	10	80	118	59	94			+1½"	700	150

Log Sheet Test #16

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:49	200	10	120	123°C	60°F	100°C		702			
2:52							708			700	
2:53	200	10	120	128	60	98					
2:54											700
2:55	200	10	120	128	59	102		702		710	
2:57							708				
2:58	200	10	120	125	59	105					
2:59								702			700
3:00	200	10	120	126	58	105					
3:01										730	
3:03	200	10	120	128	58	104					
3:04							708				700
3:06	200	10	120	128	58	103			0	650	

Log Sheet Test #17

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs
3:17	200	10	160	120°C	59°F	98°C		702			
3:20	200	10	160	120	59	100	708			725	
3:22								702			700
3:23	200	10	160	126	59	101					
3:25	200	10	160	124	59	104	708			700	
3:27											700
3:28	200	10	160	120	59	105		702			
3:30	200	10	160	122	59	94				725	
3:31							708				700
3:32	200	10	160	122	59	95			−4½"	350	

Log Sheet Test #18

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
3:43	200	10	200	118°C	60°F	102°C		702			
3:45	200	10	200	126	60	101	708			700	
3:48	200	10	200	122	59	101		702			700
3:50	200	10	200	124	59	102				700	
3:51							708				
3:53	200	10	200	121	59	104		702			700
3:55	200	10	200	121	59	103				700	
3:58	200	10	200	122	59	102	708		-7"	245	700

Log Sheet Test #19.

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
4:14	100	6	0	117°C	58°F	64°C		702			
4:17							708			700	
4:19	100	6	0	119	58	62					700
4:20								702			
4:21										700	
4:23							708				700
4:24	100	6	0	121	58	63					
4:25										700	
4:26								702			
4:27											700
4:29	100	6	0	121	58	65					
4:30							708			700	
4:32								702			700
4:34	100	6	0	121	58	64					
4:35							708			700	
4:38								702			700
4:39	100	6	0	111	58	65					
4:40							708				
4:41										700	
4:42								702			
4:44	100	6	0	116	58	65			+1½"		700

Log Sheet Test #20

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
3:34	100	8	0	115°C	59°F	68°C		702			
3:37	100	8	0	119	58	67	708			700	
3:40	100	8	0	119	58	61		702			700
3:43	100	8	0	119	57	62	708			700	
3:45	100	8	0	118	57	61		702			700
3:47	100	8	0	117	57	61	708			700	
3:49	100	8	0	118	57	61			-6"		675

Log Sheet Test #21

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
1:20	100	10"	0	120°C	58°F	62°C	708				
1:22								702		700	
1:25	100	10	0	122	58	63	708				700
1:27								702		700	
1:30	100	10	0	123	58	64	708				700
1:33								702		700	
1:35	100	10	0	119	58	65					700
1:37							708			700	
1:40	100	10	0	114	58	64		702			700
1:42							708				
1:43										700	
1:45	100	10	0	113	58	68		702			700
1:48							708			700	
1:50	100	10	0	113	58	68			-5"		400

Log Sheet Test #22

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:59	100	12	0	111°C	58°F	65°C		702			
3:02							708			700	
3:03	100	12	0	118	58	65					
3:04								702			710
3:05	100	12	0	118	58	65					
3:07							708			700	
3:08	100	12	0	118	58	65					
3:10	100	12	0	118	58	65		702			700
3:12							708			700	
3:14	100	12	0	118	58	65			-7"		675

Log Sheet Test #23

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:14	100	14	0	116°C	59°F	75°C		702			
2:18							708			700	
2:20	100	14	0	124	59	73					
2:21								702			700
2:24							708			700	
2:25	100	14	0	127	59	73					
2:27											700
2:28								702			
2:30	100	14	0	126	59	76				700	
2:31							708				
2:32											700
2:34								702			
2:35	100	14	0	128	62	76					
2:36										700	
2:38							708				
2:39											700
2:40	100	14	0	125	62	75					
2:41								702			
2:42										700	
2:44	100	14	0	126	62	75			0"		650

Log Sheet Test #24

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:11	100	14	0	115°C	58°F.	63°C		702			
2:13	100	14	0	119	58°	62					
2:14							708			700	
2:15	100	14	0	119	58	62					
2:17								702			700
2:18	100	14	0	121	58	62					
2:19										700	
2:20	100	14	0	122	58	65	708				
2:22								702			700
2:23	100	14	0	122	58	61					
2:24										700	
2:25	100	14	0	122	58	61	708				700
2:26									−2½"	125	

Log Sheet Test #25

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:32	100	16	0	116°C	58°F	69°C		702			
2:35	100	16	0	120	58	68	708			750	
2:38	100	16	0	120	58	67		702			700
2:40	100	16	0	120	58	69	708			700	
2:43	100	16	0	120	58	69		702			700
2:45	100	16	0	121	58	69					
2:46										700	
2:47	100	16	0	121	58	69			$-\frac{1}{2}$"		275

Log Sheet Test #26

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
2:10	200	8	0	125°C	60°F	94°C		702			
2:13	200	8	0	128	59	91	708			700	
2:15	200	8	0	129	59	91		702			700
2:17										700	
2:18	200	8	0	128	61	92	708				
2:19											700
2:20	200	8	0	130	60	91		702			
2:21										700	
2:22							708				
2:23	200	8	0	128	59	92					700
2:25	200	8	0	128	59	90			+2¼"	700	40

Log Sheet Test #27

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs.□"	Suction Vacuum In. Hg.	Delivery Water Lbs.□"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
11:02	200	12	0	113°C	63°F	94°C		702			
11:05	200	12	0	117	61	94	708			700	
11:07	200	12	0	121	60	92		702			700
11:09							708			700	
11:10	200	12	0	110	60	90					
11:11								702			700
11:12	200	12	0	106	59	93					
11:13										700	
11:14							708				
11:15	200	12	0	108	59	98					700
11:17	200	12	0	110	59	97			+1½"	700	80

Log Sheet Test #28

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
11:26	200	14"	0	114°C	59°F	99°C		702			
11:29							708			700	
11:30	200	14	0	126	59	99					
11:31								702			700
11:33	200	14	0	120	59	99				700	
11:34							708				
11:35	200	14	0	118	59	99					
11:36								702			700
11:37	200	14	0	121	59	99					
11:38										700	
11:39							708				
11:40											700
11:41	200	14	0	121	59	101			-4"	430	

Log Sheet Test #29

Time	Pressures			Temperatures			Supply Water			Delivery Water	
	Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Delivery Water Lbs. □"	Steam in Calorimeter	Supply Water	Delivery Water	Tank #1 Wt. Lbs.	Tank #2 Wt. Lbs.	Tank #3 Height	Tank #4 Wt. Lbs.	Tank #5 Wt. Lbs.
1:10	200	16	0	118°C	59°F	101°C		702			
1:13	200	16	0	118	59	102	708			700	
1:15	200	16	0	118	59	105		702			700
1:18	200	16	0	120	59	107	708			700	
1:20	200	16	0	122	59	107					700
1:22								702		710	
1:23	200	16	0	127	59	108					
1:25	200	16	0	126	59	107			+¼"		615

Summary of Data Tests A.

Test No.	Duration minutes	Pressures		Total Weights			Lbs. Water lifted per lb. steam	Quality of steam %	Temperatures		
		Steam in Injector Lbs. □"	Supply Vacuum In. Hg.	Supply Water Lbs.	Delivery Water Lbs.	Steam Condensed			Supply Water	Delivery Water	Steam in Calorimeter
1	30	20	6	4760	5162	262	23.66	99.8	58°F	101°F	219°F
2	30	40	6	6820	7145	325	21.00	98.5	56	106	238
3	30	60	6	7065	7410	345	20.40	98.6	58	122	226
4	30	80	6	9200	10200	1000	9.20	98	57	124	238
5	30	100	6	9600	10300	700	13.70	97.5	57	125	240
6	15	140	8	4875	5335	460	10.60	96.4	66	159	235
7	15	160	8	4890	5450	560	8.73	97.2	65.3	170	257
8	15	180	8	4875	5535	660	7.40	97	61.5	178	260
9	15	200	8	4560	5310	750	6.10	96	57.6	187	244

Summary of Data Tests B.

Test No.	Duration minutes	Pressures		Total Weights			Lbs. Water lifted per lb. steam	Quality of steam %	Temperatures		
		Steam in Injector Lbs. □"	Delivery Water Lbs. □"	Supply Water Lbs.	Delivery Water Lbs.	Steam condensed			Supply Water	Delivery Water	Steam in Calorimeter
10	15	100	0	4145	4345	200	20.7	97.6	62°F	144°F	242°F
11	30	100	40	7960	8540	580	13.7	98.5	64	152	256
12	30	100	80	7630	8210	580	13.17	98.8	62	150	259
13	15	200	0	4355	4940	585	7.44	97	59.9	197	260
14	15	200	40	4260	4800	540	7.9	95.7	59	210	238
15	15	200	80	4320	5080	760	5.68	96.2	59	199	248
16	15	200	120	4230	4890	660	6.4	97	59	216	258
17	15	200	160	3970	4600	630	6.3	96.4	59	211	250
18	15	200	180	3830	4445	615	6.2	96.4	59.3	216	250

Summary of Data. Tests C.

Test No.	Duration minutes	Pressures		Total Weights.			Lbs. Water lifted Per lb. Steam	Quality of Steam %	Temperatures.		
		Steam in Injector Lbs. □"	Suction Vacuum In. Hg.	Supply Water Lbs. Wt.	Delivery Water Lbs. Wt.	Steam condensed			Supply Water	Delivery Water	Steam in Calorimeter
19	30	100	6	7835	8400	565	13.87	97.6	58°F	147°F	242°F
20	15	100	8	3885	4175	290	13.4	97.6	57.5	113	242
21	30	100	10	7470	8100	630	11.85	97.6	58	149	242
22	15	100	12	3880	4185	305	10.8	97.7	58	149	244
23	30	100	14	6340	6950	610	10.4	98.3	60	166	254
24	15	100	14	4080	4325	245	12.6	97.8	58	144	246
25	15	100	16	3495	3825	330	10.6	97.8	64.4	163	245
26	15	200	8	4355	4940	585	7.44	97	59.9	197	260
27	15	200	12	4315	4980	665	6.48	95.5	60	201	233
28	15	200	14	4000	4630	630	6.35	96.3	59	208	246
29	15	200	16	3535	4125	590	5.99	96.3	59	223	246

- CURVES -

The following curves show graphically the results obtained from the tests herein tabulated. In all cases the endeavor was to get a smooth curve which would pass through the majority of the points and which seemed to indicate average conditions. Taken in order the curves with their co-ordinates are as follows:

Curve A_1 : Abcissae - Steam pressure at injector, lbs. per sq. inch.
: Ordinates - Gallons water lifted per hour.

Curve A_2 : Abcissae - Steam pressure at injector, lbs. per sq. inch.
: Ordinates - Lbs. water lifted per lb. steam.

Curve B_1 : Abcissae - Delivery pressures, lbs. per sq. inch.
: Ordinates - Gallons water lifted per hour.

Curve B_2 : Abcissae - Delivery pressures, lbs. per sq. inch.
: Ordinates - Lbs. water lifted per lb. steam.

Curve B_3 : Abcissae - Delivery pressures, lbs. per sq. inch.
: Ordinates - Gallons water lifted per hour.

Curve B_4 : Abcissae - Delivery pressures, lbs. per sq. inch.
: Ordinates - Lbs. water lifted per lb. steam.

Curve C_1 : Abcissae - Suction vacuum, inches of mercury.
: Ordinates - Gallons water lifted per hour.

Curve C_2 : Abcissae - Suction vacuum, inches of mercury.
: Ordinates - Lbs. water lifted per lb. steam.

Curve C_3 : Abcissae - Suction vacuum, inches of mercury.
: Ordinates - Gallons water lifted per hour.

Curve C_4 : Abcissae - Suction vacuum, inches of mercury.
: Ordinates - Lbs. water lifted per lb. steam.

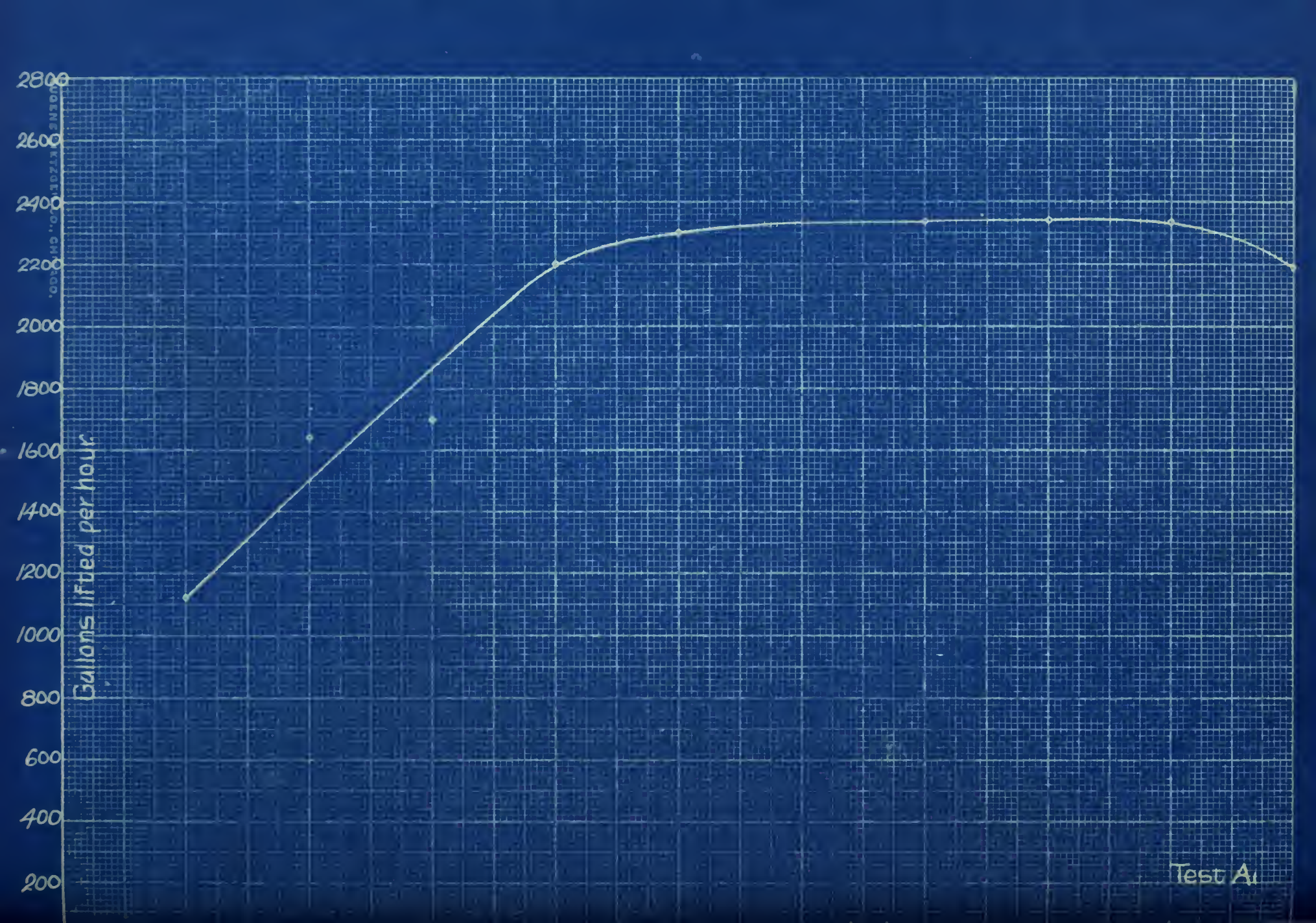
- CURVES A -

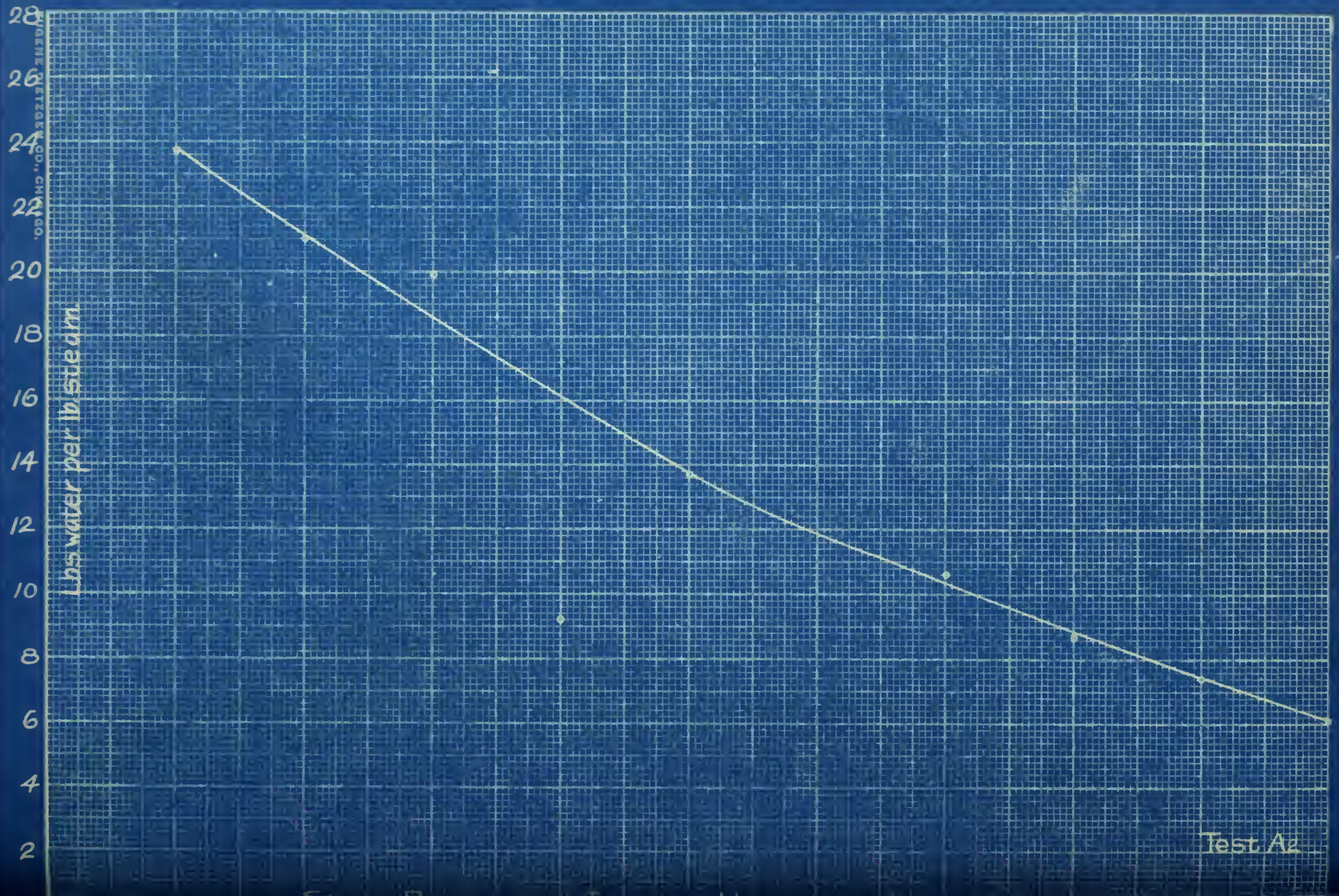
Curves with different steam pressures.

Suction temperature 58° F.

Suction lift 6 feet.

Delivery pressure 0# per sq. inch.


2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
Gallons lifted per hour
Test A1


28
26
24
22
20
18
16
14
12
10
8
6
4
2
Lbs water per lb steel dm
Test A2

- CURVES B -

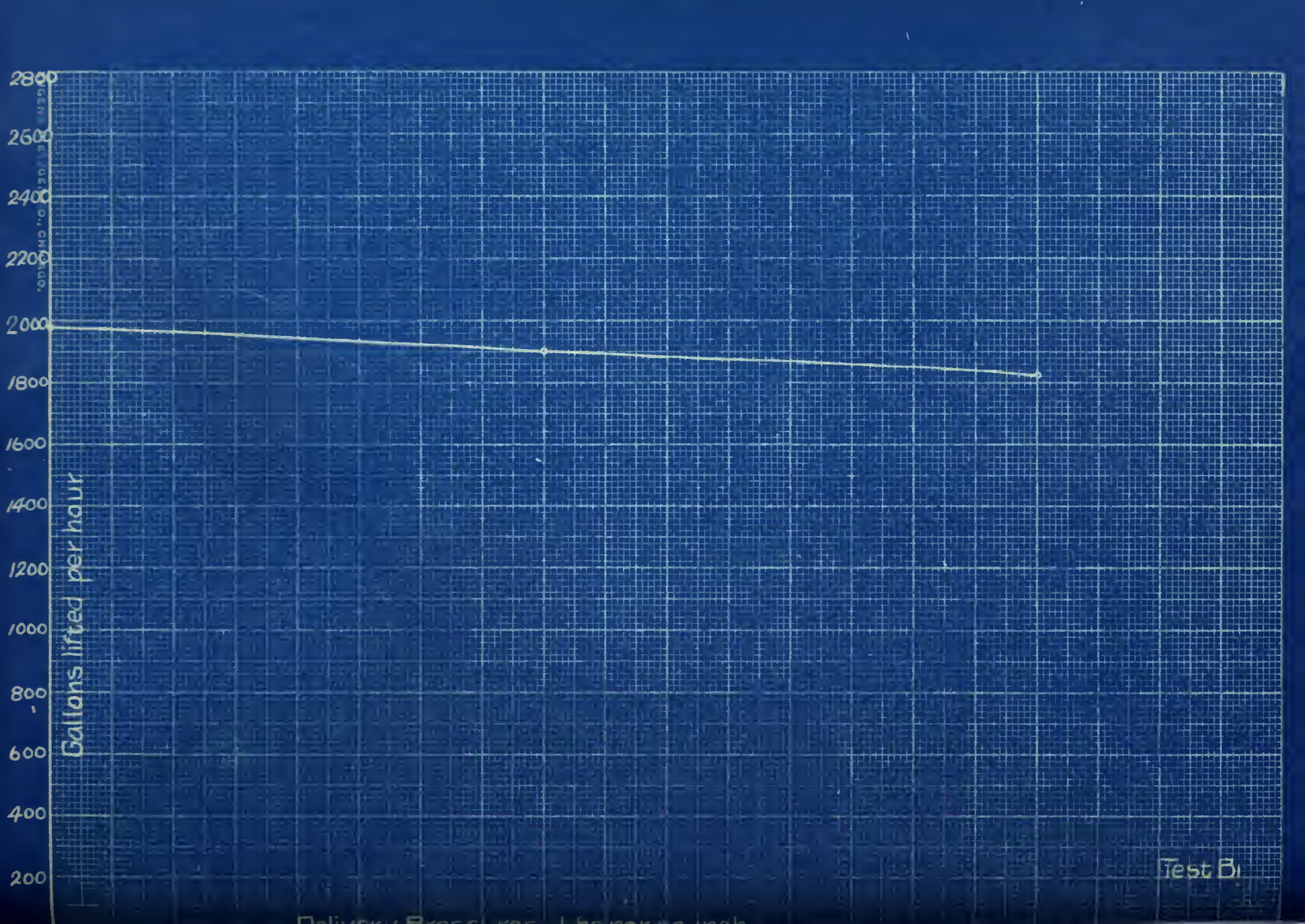
Curves with different dilivery pressures.

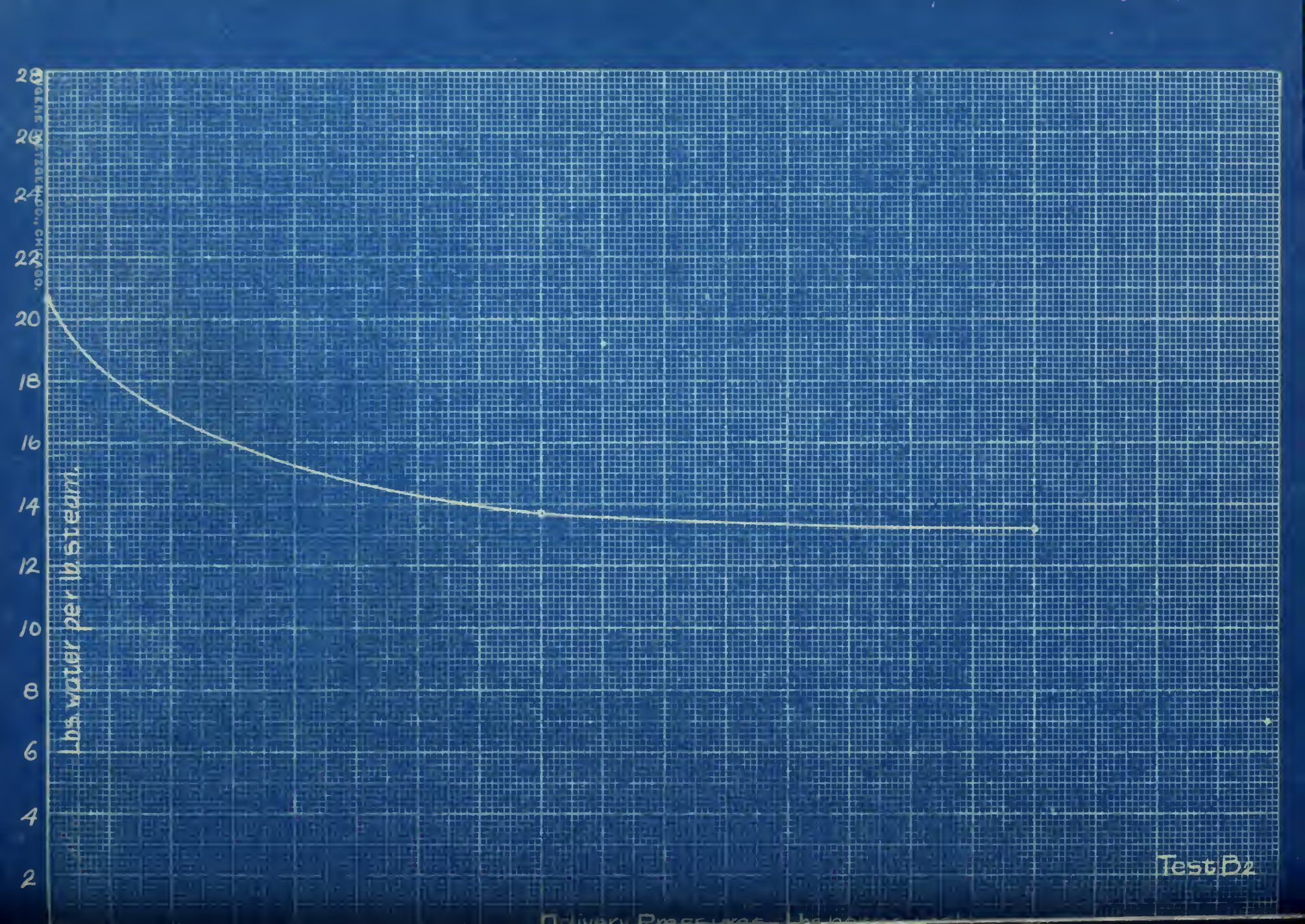
Suction temperature 58° F.

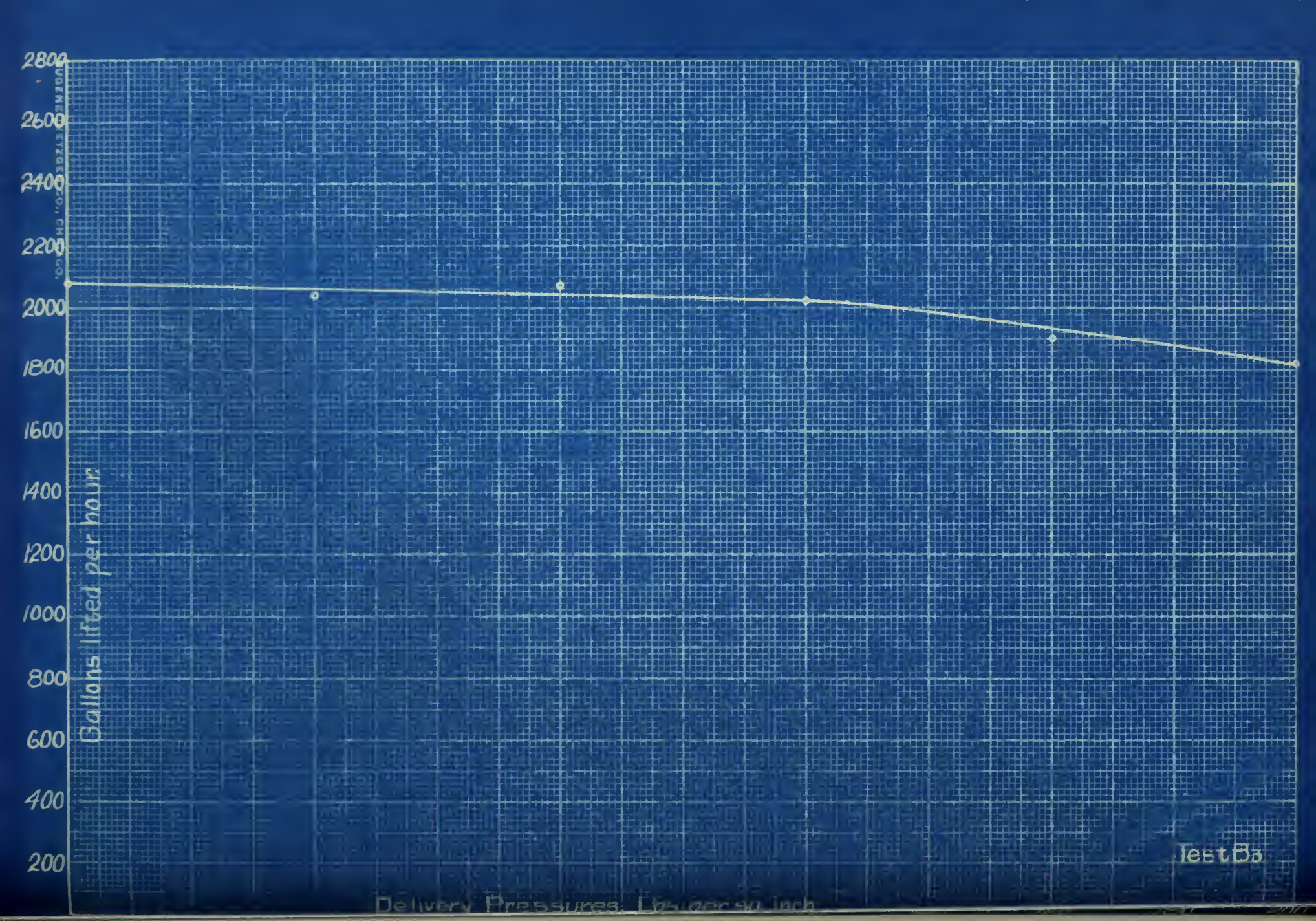
Suction lift 6 feet.

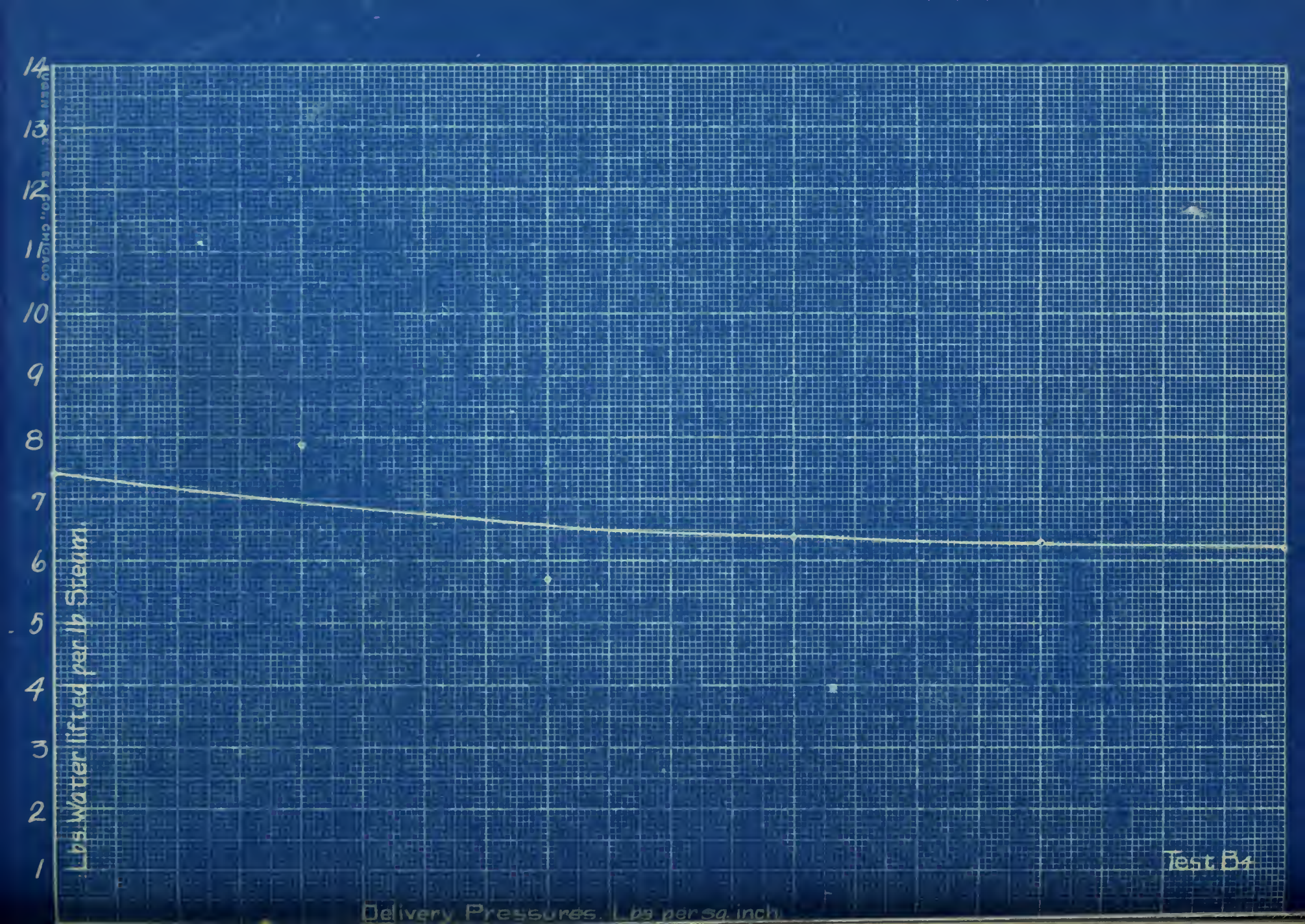
Steam pressure 100# for curves B_1 and B_2.

Steam pressure 200# for curves B_3 and B_4.


2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
Gallons lifted per hour
Test B1


Lbs water per lb steam.
28
26
24
22
20
18
16
14
12
10
8
6
4
2
Test B2


2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
Gallons lifted per hour
Test Ba
Delivery Pressures Lbs per sq inch


14
13
12
11
10
9
8
7
6
5
4
3
2
1
Lbs. Water lifted per lb Steam.
Test B4
Delivery Pressures. Lbs per sq. inch.

- CURVES C -

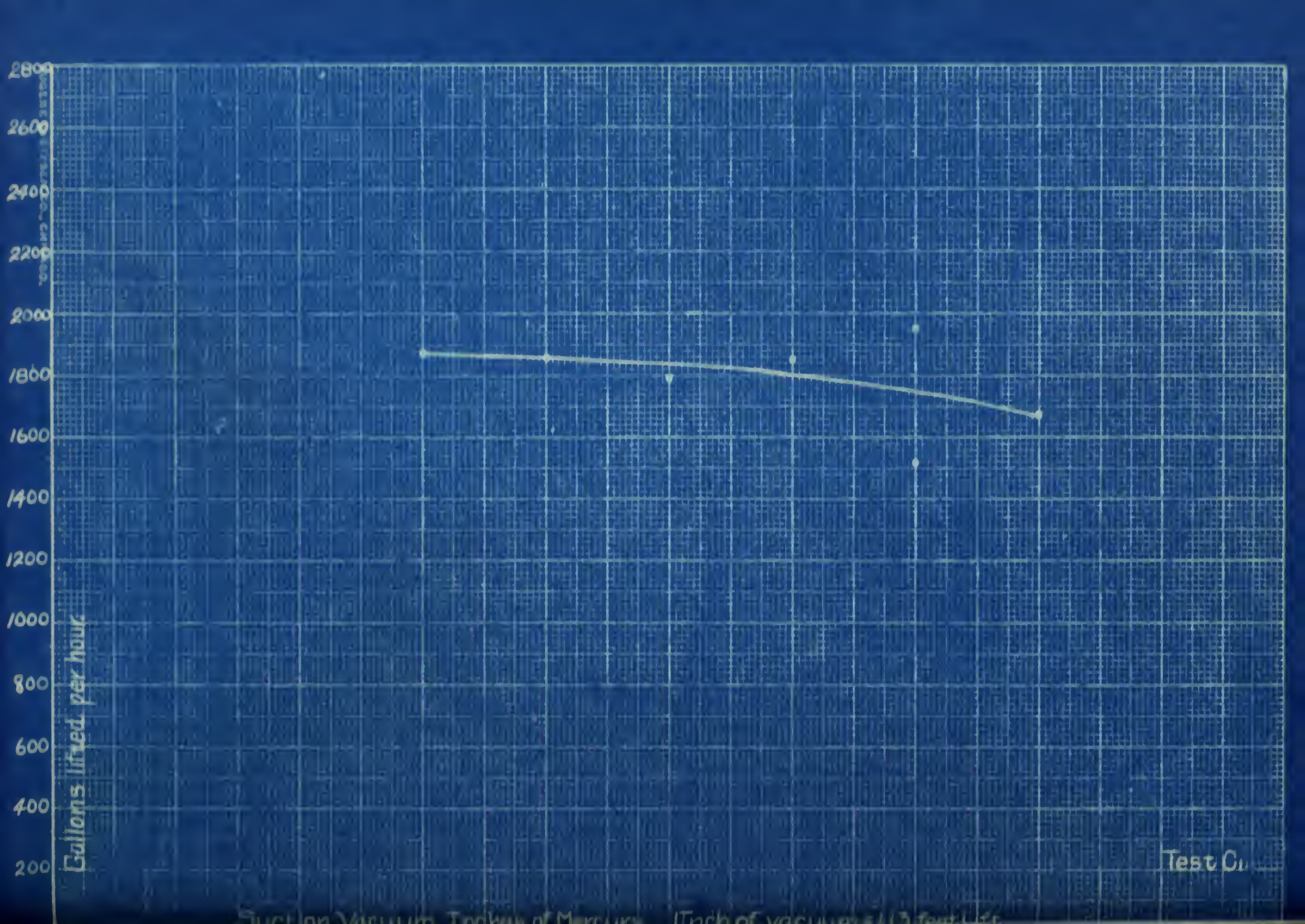
Curves with different suction lifts.

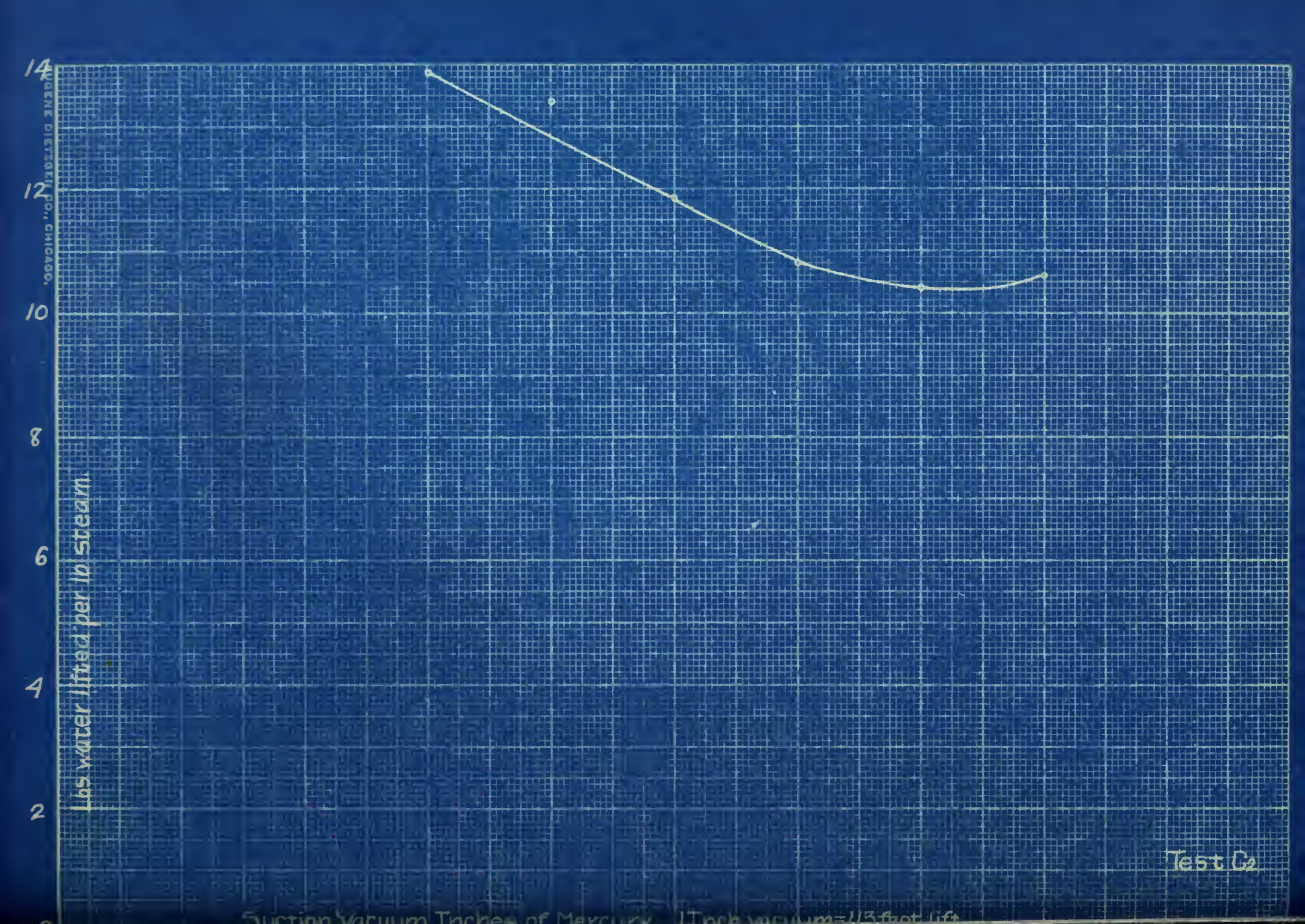
Suction temperature 58° F.

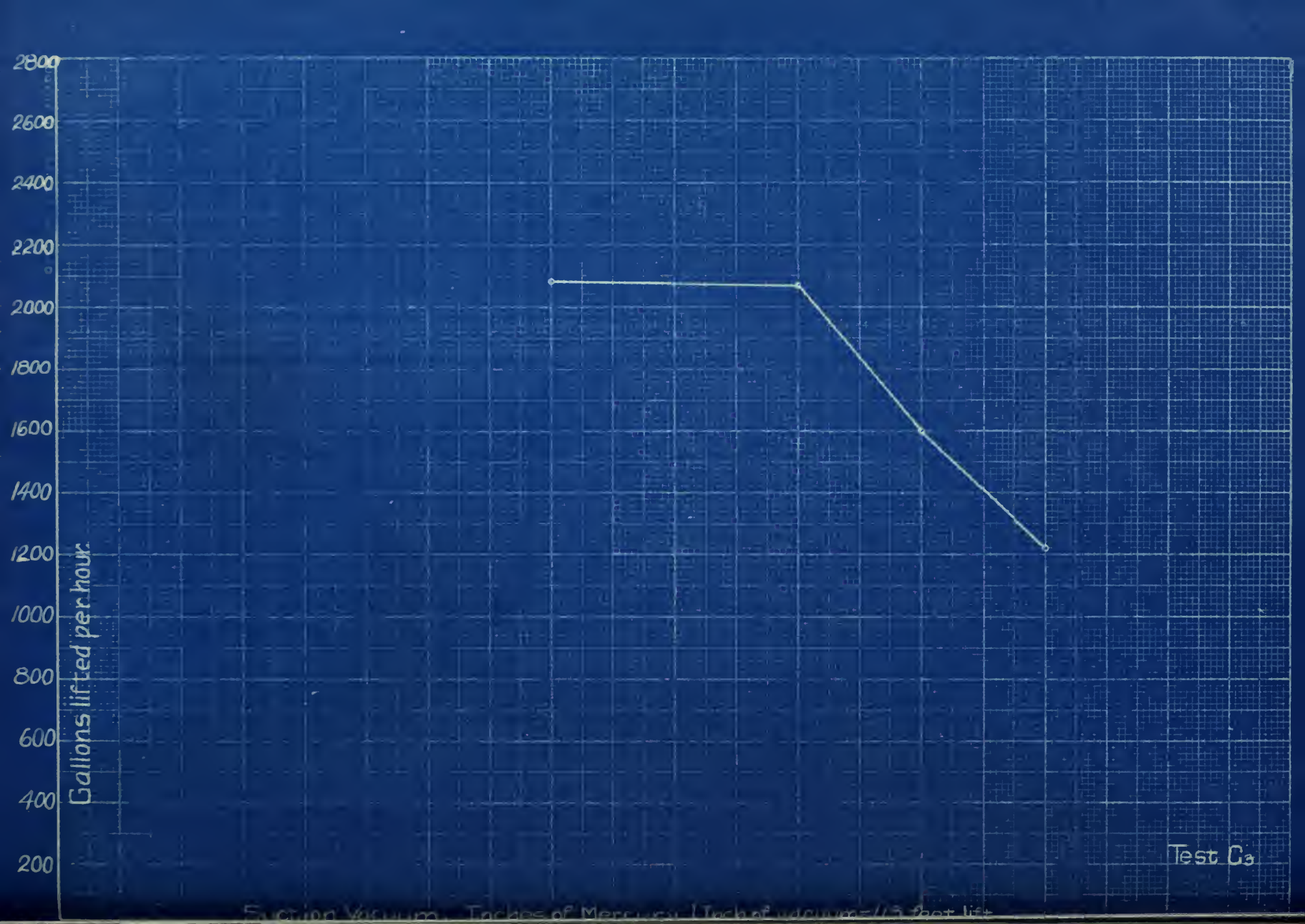
Delivery pressure $0^{\#}$ per sq. inch.

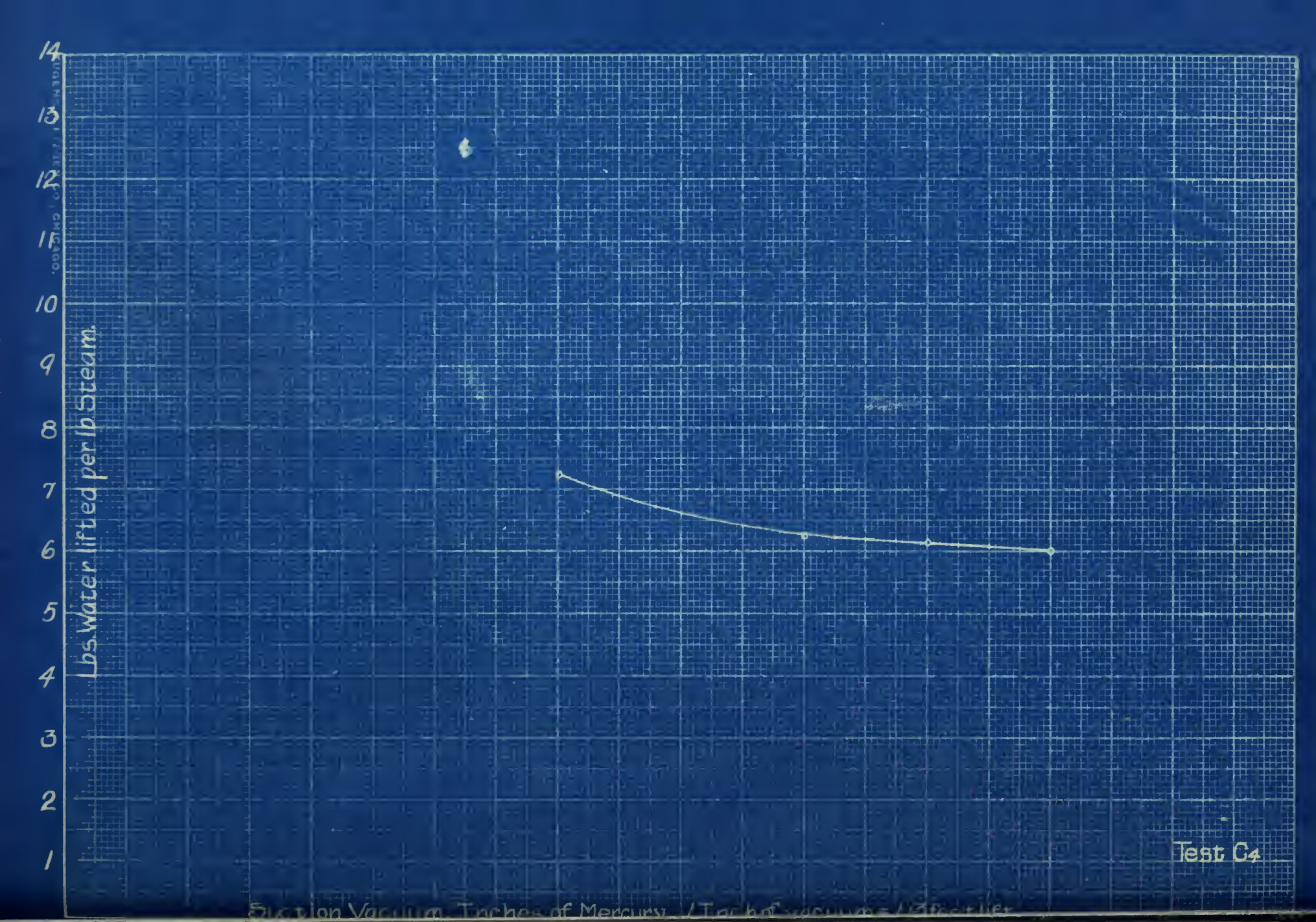
Steam pressure $100^{\#}$ for curves C_1 and C_2.

Steam pressure $200^{\#}$ for curves C_3 and C_4.


2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
Gallons lifted per hour
Test C
Suction Vacuum Inches of Mercury
Inch of vacuum = 1.13 feet


14
12
10
8
6
4
2
Lbs water lifted per lb steam
KEUFFEL & ESSER CO., CHICAGO.
Test C2
Suction Vacuum Inches of Mercury
1 Inch vacuum = 1.13 feet lift


2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
Gallons lifted per hour.
Test C3
Suction Vacuum - Inches of Mercury. 1 Inch of vacuum = 1.13 feet lift


14
13
12
11
10
9
8
7
6
5
4
3
2
1
Lbs. Water lifted per lb Steam.
Test C4
Suction Vacuum Inches of Mercury

- IV GENERAL SUMMARY -

Curve A_1 - The quantity of water lifted per hour rises gradually from 1120 gallons at 20# pressure to 2300 gallons at 100# pressure. It then remains practically constant from 100# pressure to 180# pressure and then drops back to 2190 gallons at 200# pressure.

Curve A_2 - The quantity of water lifted per lb. steam falls gradually from 23.66# at 20# pressure to 6.1# at 200# pressure.

Curve B_1 - The quantity of water lifted per hour is practically constant dropping from 1980 gallons at 0# delivery pressure to 1875 gallons at 80# delivery pressure.

Curve B_2 - The lbs. water lifted per lb. steam drops rapidly from 20.7# at 0# delivery pressure to 13.7# at 40# delivery pressure and then drops gradually to 13.2# at 80# delivery pressure.

Curve B_3 - The quantity of water lifted per hour drops gradually from 2083 gallons at 0# delivery pressure to 2024 gallons at 120# delivery pressure. It then drops more rapidly down to 1820 gallons at 200# delivery pressure. This is due probably to the fact that the delivery water was at the boiling point for the last two tests.

Curve B_4 - The lbs. water lifted per lb. steam drop gradually from 7.44# at 0# delivery pressure to 6.2# at 200# delivery pressure.

Curve C_1 - The quantity of water lifted per hour drops gradually from 1874 gallons at 6" vacuum to 1670 gallons at 16" vacuum.

Curve C_2 - The lbs. water per lb. steam drops quite rapidly from 13.87# at 6" vacuum to 10.6# at 16" vacuum.

Curve C_3 - The quantity of water lifted per hour remains practically constant up to 12" vacuum and then drops rapidly from 2070 gallons down to 1690 gallons at 16" vacuum. The delivery water was boiling for the last two tests and the rapid drop is probably due to this cause.

Curve C_4 - The lbs. water lifted per lb. steam drop gradually from 7.44# at 8" vacuum to 6# at 16" vacuum.

- V CONCLUSION -

Tests with different steam pressures at injector, the suction lift, the suction temperature, and the delivery pressure remaining constant. -

The quantity of water lifted per hour rises rapidly up to 100# pressure per sq. inch. It then remains practically constant until a pressure of 180# per sq. inch is reached and then drops back gradually

The lbs. water lifted per lb. steam drops gradually as the steam pressure at the injector rises.

Tests with different delivery pressures, the steam pressure at the injector, the suction lift, and the suction temperature remaining constant. -

The quantity of water lifted per hour drops slowly as the delivery pressure is increased, for moderate steam pressures at the injector. For high steam pressures at the injector the quantity of water lifted per hour drops more rapidly as the delivery pressure increases.

The lbs. water lifted per lb. steam drop gradually as the delivery pressure is increased.

Tests with different suction lifts, the steam pressure at the injector, the suction temperature, and the delivery pressure remaining constant.

For moderate steam pressures the quantity of water lifted per hour drops gradually as the suction lift is increased. For high steam pressures the quantity of water lifted per hour drops gradual-

ly until a lift of 12" vacuum is reached, when the delivery water becomes heated above the boiling point, and the quantity drops rapidly as the suction lift is further increased.

The lbs. water lifted per lb. steam for moderate steam pressures drops rapidly as the suction lift is increased. For high pressures the lbs. water lifted per lb. steam drops gradually as the suction lift is increased.